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KEIICHI UCHIDA[1], MANA NISHIHARA[1], TAKA SHI NANBA[1], TAKAHISA YOSHIDA[1],
YOSHINORI MIYAMOTO[1], TOSHIHARU KAKIHARA[1]
[1]*Tokyo University of Marine Science and Technology, 108-8477 Tokyo, Japan*
Email: kuchida@kaiyodai.ac.jp

ABSTRACT
Fishing equipment has improved considerably based on the experience fishermen. However, most of these developments have not considered actual observations of fish and their interactions with fishing gear. In the conge reel tube fishery in Tokyo Bay, fishermen have increased the size of escape holes in the tubes to 13 mm in order to reduce by catch of conger eels that are too small for sale. However, the effect of these escape holes on the effectiveness of the trap has not yet been clarified. We developed an underwater video camera system capable of recording approximately 12 hand used this system to observe the behavior of white spotted conger-eel *Conger myriaster* caught in conge reel tube traps in a conge reel fishery. Field experiments were conducted once a month from over a 6 month period from June 2011 to December 2011. The video camera successfully captured the following aspects of conge reel behavior: approaching the tube, entering the tube, feeding, escaping from the entrance, escaping from escape holes, and stealing bait. In addition, the video-camera also captured other fish species in the traps. The following responses were obtained when the footage was shown to fishermen: 'Just as I thought', 'Solved the mystery of how bait is stolen' and 'Fish are intelligent 'The results clarified how the traps work and provided useful information on how the traps could be improved.

KEYWORDS: white-spotted conger eel, *Conger myriaster*, behavioral observations, underwater video camera.

INTRODUCTION
The white-spotted conger eel *Conger myriaster* fishery in Tokyo Bay is economically important. The species, called "Anago" in Japanese, is an essential component of Edo-mae sushi in Japan, and in Tokyo Bay, conger eels are primarily harvested using baited tube traps called "Anago-tutu". Numerous studies on white-spotted conger eel have been conducted to date, including studies on the effectiveness of increased escape-hole size on reducing the incidental catch of small conger eels (Shimizu1997, 1999, 2003, Tokai et al. 2002, Harada et al.2007), habitat distribution (Harada et al. 2006, Uchida et al. 2007), optimal time required to trap conger eels in sufficient quantities using tubes (Yoshida et al. 2013). In a study on the effect of enlarged escape-holes on catch size, fishermen were concerned about the adverse effects of enlarged escape-holes; for example, bait could fall out of the trap or be stolen by smaller eels through the enlarged escape-holes. To address this issue, scientists examined how much bait fell out of the traps when the tubes were retrieved by fishermen and showed the obtained underwater footage to fishermen (Nakagawa 2004). In a study on optimal entrapment time, although the study measured the time required for the first entrapment, it did not examine subsequent entrapment times (Yoshida et al. 2013), which was an aspect of the fishery that fishermen were particularly interested in. In response to these concerns, we examined the behavior of conger eels in response to capture by tube-traps using a small digital video-camera housed in a custom-made waterproof case (Fig. 1).The battery time of the charged camera was approximately 100 minutes; however, after approximately 10 experiments, the built-in rechargeable battery became very weak and recording times decreased markedly. In such cases, no images of trapped conger eels were obtained even though conger eels were caught in the trap. To resolve this problem, we increased the recording time of the camera. Here we describe this new underwater video camera and discuss the captured data of conger eels caught using a tube-trap.

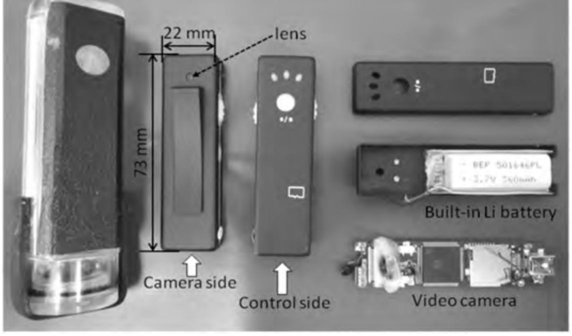

Fig. 1 Small digital video-camera (JVE-3101B); (left) custom-made waterproof housing, (right) camera components

MATERIALS AND METHODS

The original video camera (JVE-3101B, Shenzhen Mingnan Huitai Technology Co. Ltd., Guangdong in China) specifications are shown in Table 1. The current required by the camera was approximately 130-180 mA for 10 seconds of image capture. The battery life measured as a function of current consumed and battery capacity were considered typical for such a device. However, recording time decreased due to a reduction in the life of the built-in rechargeable battery. We attempted to replace the built-in rechargeable battery with an alkaline primary battery. Since the operating voltage of the camera was about 4.5 V, we combined three 1.5 V alkaline batteries in series to create a 4.5 V battery. However, the camera and the modified power source could not fit into the custom-ordered waterproof housing with the new battery supply.

Table 1 Main specifications of original JVE-3101B camera.

Manufacturer	Shenzhen Mingnan Huitai Tech. Co., Ltd.
Size	width: 22 mm, height: 73 mm, depth: 13 mm
Video file	Audio Video Interleaving (AVI), 720 x 480 resolution
Audio file	WAV (WAVeform Audio Format)
Memory	SD card, 1to 8GB
Charging time	2 to 3 hours
Battery life	1 to 2 hours
Battery type and capacity	Lithium-ion battery, 3.7 V 360mAh
Sensor and Technology	Complementary Metal Oxide Semiconductor Image Sensor (CMOS) and Pinhole
Optical Zoom	Fixed Focus

We therefore converted the housing for an underwater torch (Lumen X6, Technisub, Genova in Italia; max. depth 120 m) for use as a waterproof housing for the video camera (Fig. 2). The torch housing had sufficient space for 6 C-size batteries. Space for the camera was made by connecting two C-size batteries and one AA-size battery. If the capacity of an AA primary battery is 2000mAh, then the capacity of the new external battery would be five times that of the built-in battery, and consequently, the expected recording time would be more than 500 minutes. Video files were saved to a micro SD card as a 1.6GB AVI file every 50 minutes. We used a 32 GB SD card to record 20 files, or more than16 hours of footage. However, the operating time of the LumenX6 underwater torch was 6 hours, which was less than the video recording time. We thereforeused an LED light with an operation time of more than 24 hours in the developed camera system. Fig. 3 shows a schematic of the final circuit diagram for the camera*.

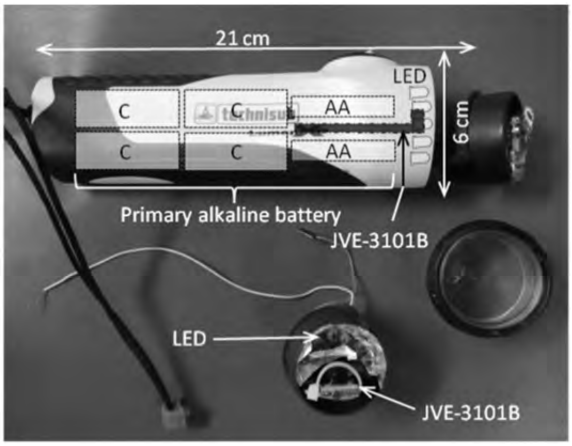

Fig. 2 Underwater camera designed from converted underwater torch.

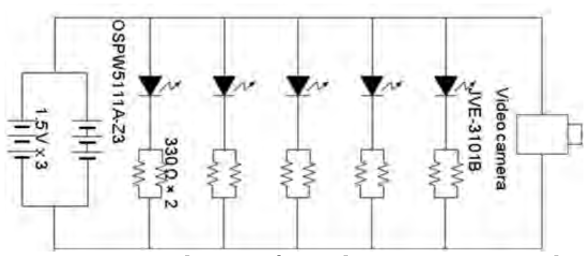

Fig. 3 Circuit diagram for underwater camera with LED light.

The developed camera was then tested in two types of tube traps (Fig. 4); the commercial fishery-type, which measured 80 cm and had a diameter of 10 cm, and traps that were 20 cm longer than the normal type; the additional length made up for the space used to house the camera and light. Field experiments were conducted on a conger eel tube fishing boat (Uchida *et al*. 2007), the *Kinki-maru* No. 6 (17.5 m, 11 t), belonging to the Yokohama City Fisheries Cooperative Association from Kanagawa Prefecture from June 2011 to December 2011.

*We cannot be held responsible for any damages arising from replicating this method.

This paper describes the results obtained on 24⁻25 October and 21⁻22 November 2011.Fishermendeployed approximately 600 tube-traps at one time. The traps were set near the shore and in the center of the bay in the afternoon at depths ranging from 6 to 40 m (Figs. 5 and 6).All of the traps were retrieved the next morning. Bait consisted of a mixture of frozen anchovy and frozen squid weighing 300 g, which was the same as that used by commercial fishermen. The position of each tube trap was recorded at the time each trap was set. The number of conger eels caught, the condition of leftover bait, and the depth of each tube trap was noted when the traps were retrieved.

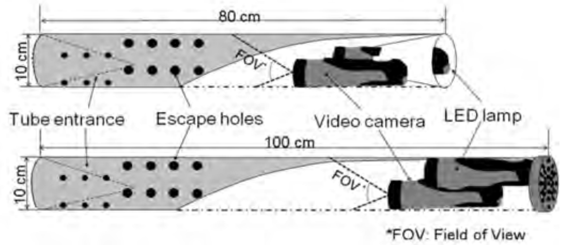

Fig. 4 Outline of video camera placement and illumination in experimental tube trap.

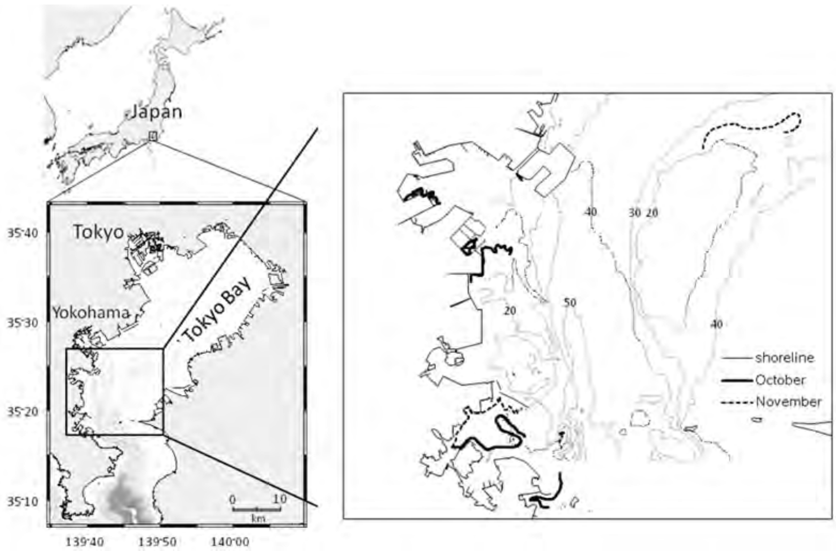

Fig. 5 Map of tube trap location in Tokyo Bay, Japan; dotted lines along the coast indicate isobaths.

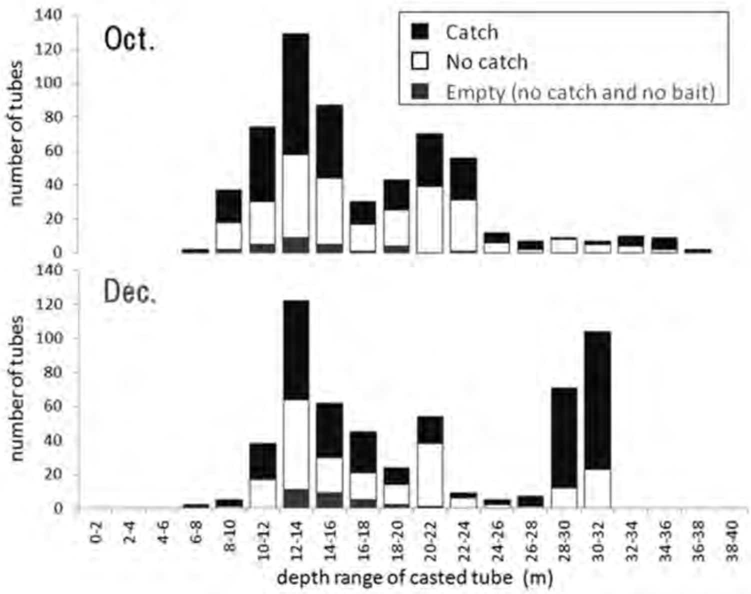

Fig. 6 Frequency histogram of empty or full traps at different depths.

RESULTS

In October, conger eel fishermen deployed a total of 584 tube traps. Of these traps, 295 caught conger eels. Of the remaining 289 traps, 27 did not have any leftover bait, even though they contained no eels and no evidence of feeding damage by Gammaridea was observed. In November, fishermen deployed 548 tube-traps, and of these, 318 traps caught conger eels. Of the remaining 230 traps that did not contain any eels, 29 had no leftover bait and there was no evidence of feeding damage by Gammaridea. These empty tarps had been deployed in shallow water at depths of 10 to 20 m (Fig. 6).

The 17 files (about 14 hours) were recorded by one developed underwater camera. In the underwater camera-trap tube traps, 3 of 4 and 2 of 5 successfully captured conger eels in October and November, respectively (Table 2). The catch consisted mainly of large conger eels measuring 48.2 to 70.3 cm (166 to 562 g). By contrast, the three video cameras, which were no catch, took a conger eel existed in the tube-tarp. The video camera footage revealed that conger eels fed as follows: conger eels were attracted into the tube trap by the bait. The funnel-shape of the trap entrance ensured that the eels were unable to escape. In addition, the camera also captured the behavior of conger eel in the tube-trap, such as pulling at the bait from the entrance, searching for bait, feeding, and easily entering and leaving the trap (Fig. 7). These behaviors would otherwise have been difficult for the fishermen to perceive, even though they have retrieved many empty tube-traps. The video camera revealed that the bait had been removed by conger eels that had entered the traps on six occasions. Interestingly, the conger eels that escaped were mostly large eels. However, Gammaridea were also responsible for depleting the bait in the traps, requiring as little as 2 h to reduce the bait to anchovy bones and squid cartilage (Fig. 8). After the tube-traps landed on the sea floor, the video camera recorded the first conger eels visiting 5 out of 7 traps at around sunset.

Table 2Shooting depth and time, time of first arrival, trapping time, catch size and total length of catch.

	No.	Depth (m)	Time			Catch size*	Total length (cm)
			Shooting	Arrival	Trapped		
October	1	8.8	14:11			no	70.3
	2	12.1	14:13	17:11	17:26	c:1	
	3	10.7	15:23	17:50	18:00, 21:01, 21.25	c:2	50.6, 48.2
	4	9.7	15:28	16:38	16:38, 17:52	c:2	61.8. 49.8
November	1	11.7	14:23	14:26	16:07, 17:49	c:1	56.6
	2	16.9	14:31	16:35	18:17	no	
	3	26.9	15:59	16:51	17:10	no	
	4	27.2	16:05		17:17, 17:26	h:1	21
	5	27.8	16:10	16:28	17:19, 17:26 unknown	c:2 h:2	56.0, 55.8 38.3, 32.0

*: c, white spotted conger eel; h,hagfish *Eptatretus burger*; no, no catch.
Sunset: 16:57 in October and 16:33 in November.

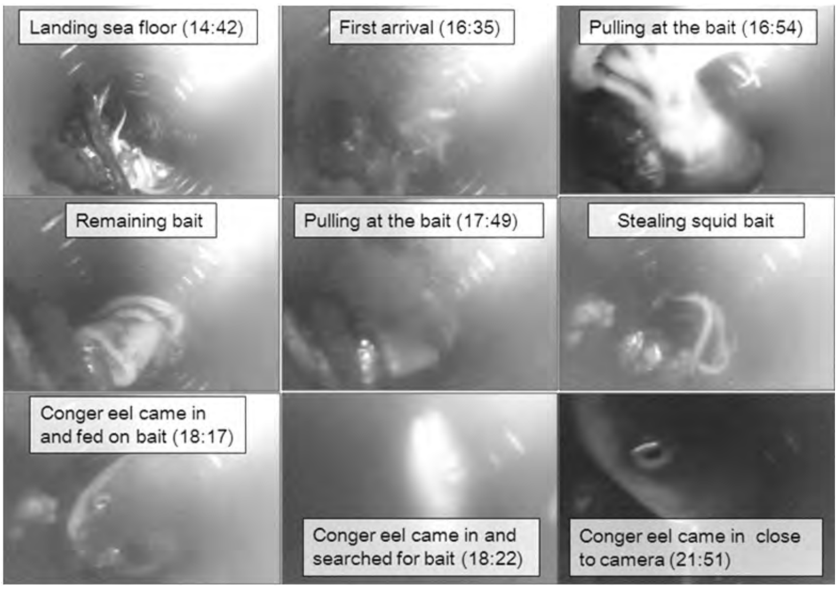

Fig. 7 Behaviors of conger eels in the No. 2 experimental tube-trap in November.

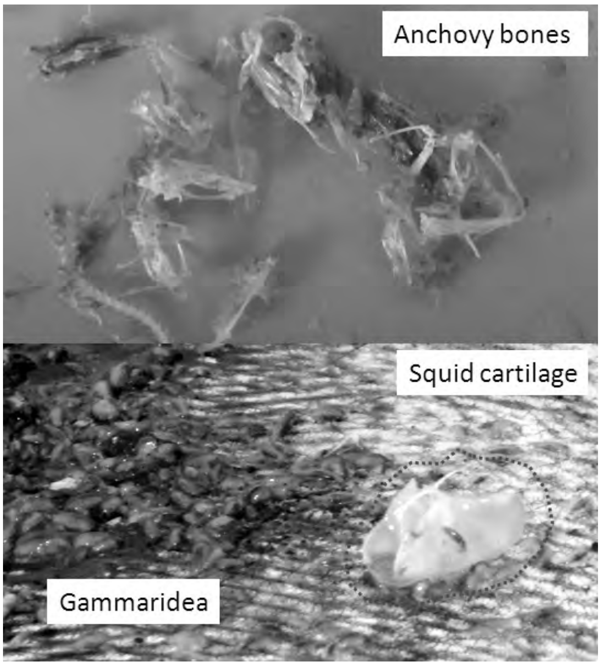

Fig. 8 Photos of leftover bait eaten by Gammaridea; only anchovy bones and squid cartilage remained

DISCUSSION

After late autumn, the shallow water environment close to the shore is considered to be good habitat for conger eels. This is opposite to the situation in summer when these areas are low in oxygen. Fishermen have long known that large conger eels can be found in these shallow coastal areas during the fall and winter. In October and November fisherman aimed to catch these large conger eels. This study is the first to record the behavior of conger eels in tube-traps. Using the developed underwater camera, many large conger eels (>50 cm) were observed to have escaped from the traps. The weight of a conger eel >50cm is approximately 300 g. Since 27and 29 empty traps were retrieved in October and November, the potential weight of the lost catch would be about 8 to 9 kg. In response to this finding, fishermen had two ideas. One was to increase the length of the trap to retain large conge reel, another was that a failure to catch large conger eels is actually important for reproduction.

Yoshida et al. 2013 investigated the time required for conger eels to become trapped at depths of 20 to 30 m. Compared to previous studies, which reported that conger eels arrived about one hour after the traps were deployed, the conger eels in this study arrived later. In this study, the video footage obtained at depths of 9 to 17 musing the developed underwater camera showed that these depths were shallow enough to allow sunlight to penetrate the escape holes before sunset. Most of the first arrivals occurred at around sunset after the sea floor became dark. Since the sea floor of shallow-water areas remains lighter than the seafloor areas of deeper areas, it was inferred that the conger eels are most active shortly after dark. In addition, if the area has high numbers of Gammaridea, the bait in the trap would be consumed in about 2 hours. This means that deploying the traps early (e.g. “several hours before sunset”), which fishermen believed was best, is not always good for maximizing catch.

Recently, numerous camera loggers and underwater video camera shave been developed for sale. By using these electronic devices, which are improving in terms of performance, size and price, it is possible to obtain more information about underwater environments and their associated biota.

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